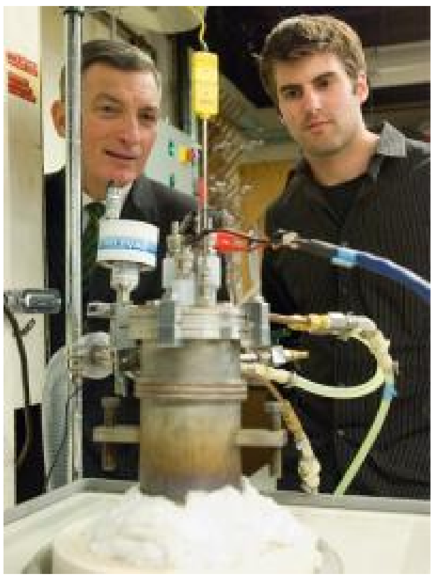
Liquid battery big enough for the electric grid?

November 19 2009, by David L. Chandler



Professor Donald Sadoway and graduate student David Bradwell observe one of their small test batteries in the lab. The battery itself is inside the heavily insulated metal cylinder at center, which heats it to 700 degrees Celcius, while the wires at top charge up the battery and measure its performance. Photo: Patrick Gillooly

(PhysOrg.com) -- There's one major drawback to most proposed renewable-energy sources: their variability. The sun doesn't shine at night, the wind doesn’t always blow, and tides, waves and currents fluctuate. That's why many researchers have been pursuing ways of storing the power generated by these sources so that it can be used when it's needed.

So far, those solutions have tended to be too expensive, limited to only certain areas, or difficult to scale up sufficiently to meet the demands. Many researchers are struggling to overcome these limitations, but MIT professor Donald Sadoway has come up with an innovative approach that has garnered significant interest — and some major funding.

The idea is to build an entirely new kind of battery, whose key components would be kept at high temperature so that they would stay entirely in liquid form. The experimental devices currently being tested in Sadoway's lab work in a way that's never been attempted in batteries before.

This month, the newly established federal agency ARPA-E (Advanced Research Projects Agency, Energy) announced its first 37 energy-research grants out of a pool of 3,600 applications, and Sadoway's project to develop utility-scale batteries received one of the largest sums — almost $7 million over five years. And within a few days of the ARPA-E announcement, the French oil company Total — the world's fifth-largest — announced a $4 million, five-year joint venture with MIT to develop a smaller-scale version of the same technology, suitable for use in individual homes or other buildings.

Because the technology is being patented and could lead to very large-scale commercialization, Sadoway will not discuss the details of the materials being used. But both Sadoway and ARPA-E say the battery is based on low-cost, domestically available liquid metals that have the potential to shatter the cost barrier to large-scale energy storage as part of the nation's energy grid. In announcing its funding of Sadoway's work, ARPA-E said the battery technology "could revolutionize the way electricity is used and produced on the grid, enabling round-the-clock power from America's wind and solar power resources, increasing the stability of the grid, and making blackouts a thing of the past."

Andrew Chung, a principal at Lightspeed Venture Partners in Menlo Park, Calif., which has no equity stake in Sadoway's project at this point, says that "grid-scale storage is an area that's set to explode in the next decade or so," and is one that his company is following closely. The liquid battery concept Sadoway is developing "is an exciting approach to solving the problem," he says.

Big is beautiful

Most battery research, Sadoway says, has been aimed at improving storage for portable or mobile systems such as cellphones, computers and cars. The requirements for such systems, including very low weight and high safety, are very different from the needs of a grid-scale, fixed-location battery system. "What I did was completely ignore the conventional technology used for portable power," he says. The different set of requirements for stationary systems "opens up a whole new range of possibilities."

A large, utility-owned system "doesn't have to be crash-worthy; it doesn't have to be 'idiot-proof' because it won't be in the hands of the consumer." And while consumers are willing to pay high prices, pound-for-pound, for the small batteries used in high-value portable devices, the biggest constraint on utility-sized systems is cost. In order to compete with present fossil-fuel power systems, he says, "it has got to be cheap to build, cheap to maintain, last a long time with minimal maintenance, and store enormous amounts of energy."

And so the new liquid batteries that Sadoway and his team, including graduate student David Bradwell, are designing use low-cost, abundant materials. The basic principle is to place three layers of liquid inside a container: Two different metal alloys, and one layer of a salt. The three materials are chosen so that they have different densities that allow them to separate naturally into three distinct layers, with the salt in the middle separating the two metal layers —like novelty drinks with different layers.

The energy is stored in the liquid metals that want to react with one another but can do so only by transferring ions — electrically charged atoms of one of the metals — across the electrolyte, which results in the flow of electric current out of the battery. When the battery is being charged, some ions migrate through the insulating salt layer to collect at one of the terminals. Then, when the power is being drained from the battery, those ions migrate back through the salt and collect at the opposite terminal.

The whole device is kept at a high temperature, around 700 degrees Celsius, so that the layers remain molten. In the small devices being tested in the lab, maintaining this temperature requires an outside heater, but Sadoway says that in the full-scale version, the electrical current being pumped into, or out of, the battery will be sufficient to maintain that temperature without any outside heat source.

While some previous battery technologies have used one liquid-metal component, this is the first design for an all-liquid battery system, Sadoway says. “Solid components in batteries are speed bumps. When you want ultra-high current, you don’t want any solids.”

Inspiration from aluminum

The initial inspiration for the idea came from thinking about a very different technology, Sadoway says: one of the biggest users of electrical energy, aluminum smelting plants. Sadoway realized that this was one of the few existing examples of a system that could sustain extremely high levels of electrical current over a sustained period of years at a time. “It’s an electrochemical process that runs at high temperatures, and at a current of hundreds of thousands of amps," he says. In a sense, the new concept is like an aluminum plant running in reverse, producing power instead of consuming it.

Chung says that from the point of view of a venture capitalist, the research is particularly intriguing for several reasons. Not only does it offer the potential to significantly lower the cost and increase cycle life [the number of times it can be charged and discharged] of large-scale electricity storage, but it also suggests that the risk typically associated with an early stage research project may be lower because the system draws on decades of experience in the design and operation of aluminum production facilities. "That gives us added confidence that some of the targets around cost, scalability and safety have merit," he says.

The team is now testing a number of different variations of the exact composition of the materials in the three layers, and of the design of the overall device. Sadoway says that thanks to initial funding through the Deshpande Center and the Chesonis Family Foundation, he and his team were able to develop the concept to the point of demonstrating a proof-of-principle at the laboratory scale. That, in turn, made it possible to get the large grants to develop the technology further.

"It's an example of work that sprang from basic science, was developed to a pilot scale, and now is being scaled up to have a real transformational impact in the world," says Ernest Moniz, director of the MIT Energy Initiative.

The laboratory tests have provided "some measure of confidence," Sadoway says. But many more tests will be needed to "demonstrate that the idea is scalable to industrial size, at competitive cost." But while he is very confident that it will all work, there are a lot of unknowns, he says, including how to design and build the necessary containers, electrical control systems, and connections.

“We’re talking about batteries of a size never seen before,” he says. And the system they develop has to include everything, including control systems and charger electronics on an unprecedented scale.

For Sadoway, the project is worth pursuing despite its daunting challenges, because the potential impact is so great. “I’m not doing this because I want another journal publication,” Sadoway says. “It’s about making a difference … It’s an opportunity to invent our way out of the energy problem.”

Provided by Massachusetts Institute of Technology (news : web)

Citation: Liquid battery big enough for the electric grid? (2009, November 19) retrieved 26 April 2024 from https://phys.org/news/2009-11-liquid-battery-big-electric-grid.html